CCDSPEC

User Guide

Version 2.2 February 2015

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1: Introduction

Elliott Instruments CCDSPEC has been specially designed for amateur astronomers and small observatories, to take spectra of astronomical objects from stars and nebulae, to the red-shifts of galaxies and supernovae.

The instrument can be used with most astronomical CCD cameras, so this is ideal for those amateurs who already have their own CCD camera. CCDSPEC has a slit viewing port, to enable the star or galaxy to be placed on the slit and to allow guiding for long exposures, which are typically needed for faint objects.

Guiding can be either manual via an eyepiece or by an auto-guider attached to the slit viewing port.

The instrument is essentially “Plug and Play” apart from focussing, as the slit and dispersion are fixed and the input aperture is M42x0.75 T2 mount, output is T2 mount or C mount.

The CCDSPEC is supplied with *PCSpectra* software for analysis and display of your data.

2: Unpacking and checking

Please check that all items are present.

CCDSPEC
M42 T-mount to C-Mount Camera adapter
1.25” Telescope adapter
2 Allen Keys 1.5mm, 2.5mm
CCDSPEC User Guide
PCSpectra User Guide
CCDSPEC CD-ROM

3: Getting to know your CCDSPEC

Most of the CCDSPEC components are pre-aligned and locked in place and should need no adjustment. There are mounts for telescope, CCD Camera and eyepiece or auto-guider.

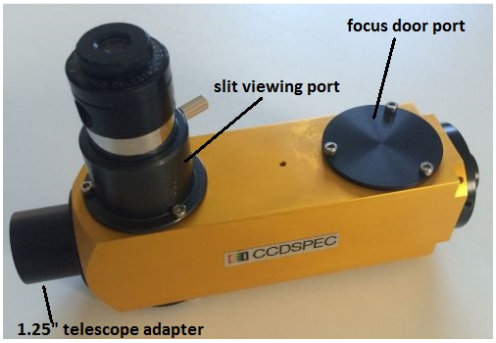

Figure 1 - Side view of CCDSPEC

Figure 2 - Camera end of CCSPEC

The telescope end of CCDSPEC has an M42 T-mount thread which can receive any telescope adapter, but is shown here with a standard 1.25” adapter.

The slit viewing port takes any 1.25” eyepiece or 1.25” auto-guider.

The Focus Port Door gives access to the focus scale drum to allow exact focussing of the spectrum on to your CCD Camera.

4: Fitting your CCD camera to CCDSPEC

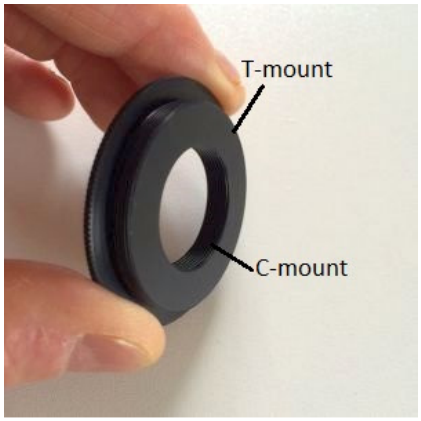

Figure 3 - Fitting the T-mount adapter

Figure 4 - Locking the 4 retaining screws

The CCD camera is mounted via an M42 T-mount to C-mount adapter (Figure3). The C-mount is screwed on to the CCDSPEC camera lens and then the T-mount is screwed into the CCD camera.

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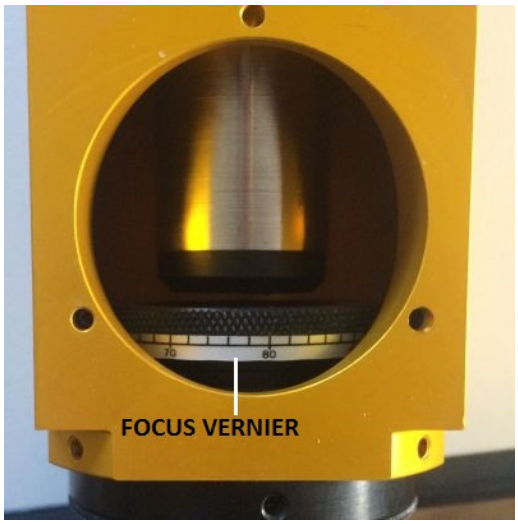

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Figure 5 - Focus Port with door removed

5: INITIAL ALIGNMENT OF CCDSPEC

Illuminate the slit with a spectral calibration light, which can be a fluorescent lamp or an energy saving lamp, which will contain mercury and other elements and will show an emission line spectrum. To make sure the slit is evenly illuminated it helps if you place a diffuser over the eyepiece mount. “Scotch Tape” or tracing paper cut to size are perfect for this, as shown in the Figure 6.

Figure 6 - Diffuser on eyepiece mount

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Switch on your CCD camera and operate it in focussing mode where you can see an image several times a second. The CCD display should now show a spectrum which is probably out of focus and at some random angle (see Figure 7).

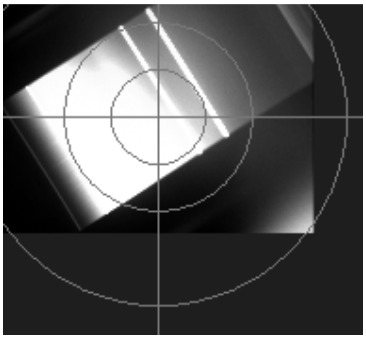


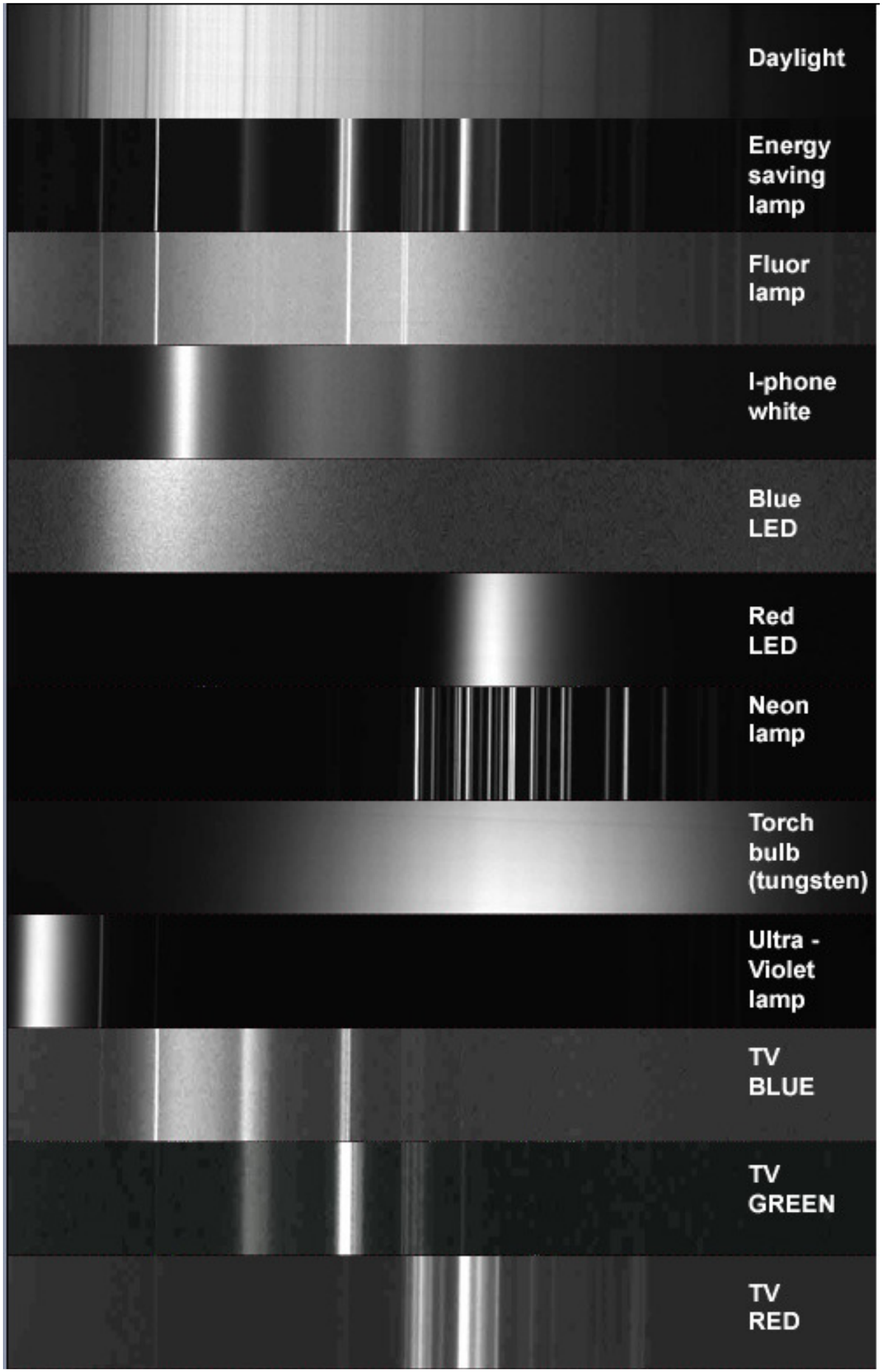
Figure 7 – A spectrum before alignment

Remove the Focus Port Door using the 2.5 mm Allen key, and rotate the exposed focus vernier drum (Figure 5) until the emission lines are approximately focussed.

Now rotate the CCD camera and the M42 mount in the V-groove until the emission lines are exactly lined up, so they are parallel to pixels on the CCD. It is conventional to have wavelength increasing left to right with pixel number. The *PCSpectra* Software assumes that wavelength increases with pixel number. Users of ATIK *Artemis* software need to select the Camera → Rotate 180° option for consistency.

To establish which way round the spectrum is oriented you will need to be able to recognise a spectrum. This is most easily done by pointing the CCSDSPEC at sources of light found in the home..

Daylight has the characteristic spectrum of the Sun, with the many Fraunhofer Absorption lines, but energy saving lights, computer monitors, TV displays and even I-phones display characteristic spectra. Some power indicator lamps in mains adapters use Neon lamps which have many lines although some now use red LED lamps. Figure 7a below shows a picture of the spectrum of many common light sources found in the home to allow you to check that you have your CCD camera aligned the correct way round which is with the BLUE part of the spectrum on the LEFT and the RED end of the spectrum to the right.



BLUE RED

Figure 7a – The spectra of various light sources to show correct alignment of CCD camera

Once the CCD is aligned with the spectrum, tighten up all 4 locking screws using the 1.5mm Allen key (See Figure 4).

6: FOCUSSING of CCDSPEC

There are a few simple ways to do the final focussing of the CCDSPEC. Each require you to operate the CCD in its 'focus mode' so you can see the spectrum in real time with frames typically being displayed a few times a second.

We recommend the use of *Nebulosity* software from Stark-Labs as it has an excellent focus option. This may be downloaded from http://www.stark-labs.com/nebulosity.html

6.1 Daylight

Daylight is just scattered sunlight and so contains the Solar spectrum, which includes many Fraunhofer absorption lines as shown in Figure 8 below.

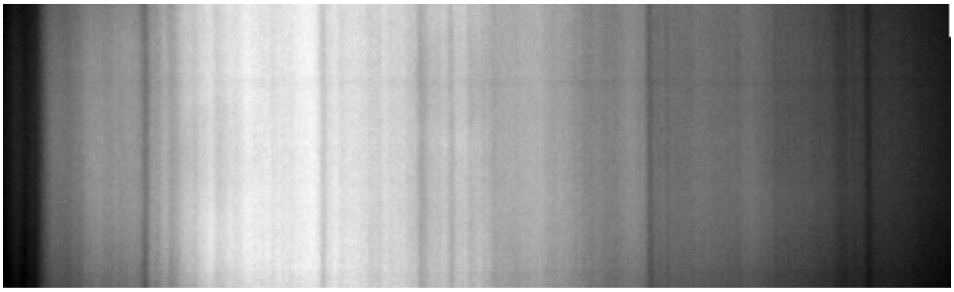


Figure 8 – The daylight spectrum showing the Fraunhofer absorption lines in the Sun

Simply adjust the focus vernier until the narrow absorption lines are well focussed in the middle of the spectrum.

6.2 Energy Saving lamps

Many of the energy saving lamps used in your home have complex spectra showing many emission lines and these can be used too. Simply look at the spectrum in real time and adjust the focus vernier until any fine line features are sharply focussed. An energy saving lamp spectrum which is well focussed is shown below in Figure 9.

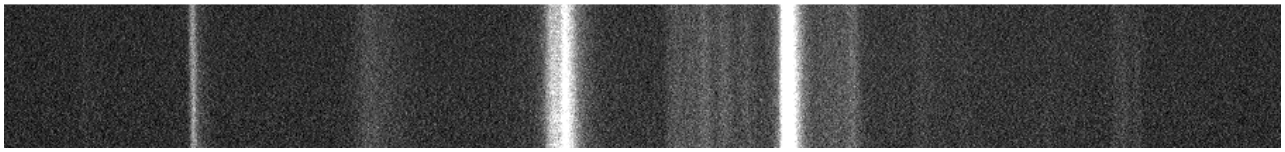


Figure 9 – Spectrum of a domestic energy saving lamp

6.3 Mercury Yellow Doublet

Probably the best way to focus the CCDSPEC is to look at a very close doublet spectral line such as the yellow Mercury doublet. For this you will need a mercury lamp, but many fluorescent lamps and cold cathode lamps use mercury vapour so these can be used too. The spectrum will look similar to the one below from a cold cathode lamp.

Figure 10 – Spectrum of a cold cathode lamp showing the mercury lines

violet blue green yellow doublet

Using your CCD acquisition program in its focus mode, where you can see the spectrum in real time, rotate the focus vernier to get the best focus and record the reading of the vernier. The focus control is scaled 0-100. If the focus it turned out 1.5 turns from zero, then the scale reading is 150. The nominal focus should be about 85. Do not turn the focus more than about 1.7turns out (170). If focus cannot be achieved in the range 0-170, contact EI Ltd for advice.

In Figure 11, the *Nebulosity* software shows the spectral lines and graph in real time, so it is easy to judge the best focus, when the lines are clearly resolved.

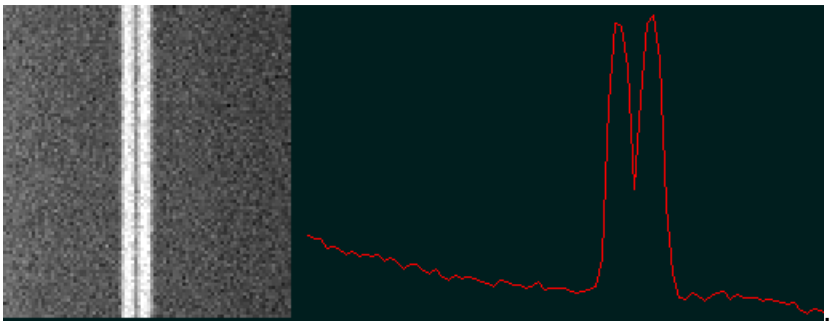


Figure 11 – Showing the focussing of the mercury doublet using *Nebulosity* software

Once the instrument is focussed, re-fit the Focus Port Door and replace the door screws using the 2.5 mm Allen key.

7: Taking Your First Astronomical Spectrum

Before attaching the CCDSPEC to your telescope it is best to focus the slit viewing port. Look down the slit viewing port, by using an eyepiece, webcam or other electronic imaging device, and move the eyepiece or other imaging device up or down until you can see the CCDSPEC slit clearly in focus (as shown in Figure 12) and then lock in place.

Attach the CCDSPEC and CCD camera to your telescope by using any suitable T-mount adapter. For most purposes, especially with an equatorially mounted telescope it is best for the slit to be orientated East-West, which is when the eyepiece mount is upright. Make sure the locking screws attaching the CCDSPEC to the telescope are locked tight.

The combined weight of the CCDSPEC and CCD camera will be typically 1.6 kg, but of course the actual weight will depend on your camera and slit viewing device etc. You should make sure that your telescope is properly balanced after attaching the CCDSPEC to avoid damage to your drives and mount, and also to ensure reliable tracking during long exposures.

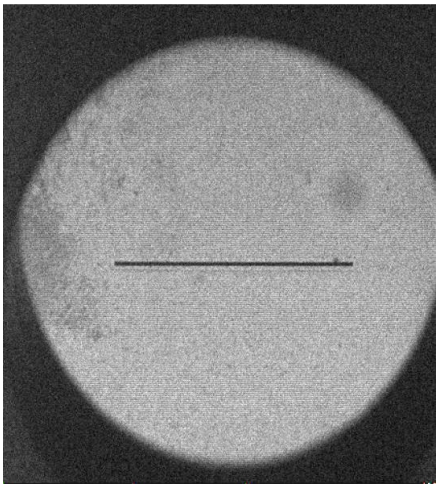


Figure 12 – Slit in focus

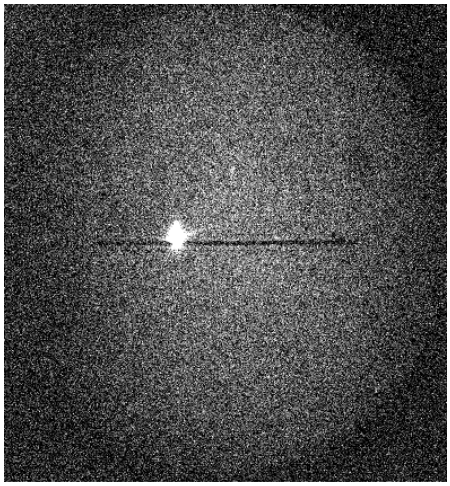


Figure 13 - A star nearly on the slit

During daylight you can simply take a spectrum of the blue sky and you will see the Fraunhofer absorption lines from the Solar spectrum. **WARNING: NEVER POINT THE CCDSPEC AT THE SUN!**

Centre the object of interest and then use the telescope's focuser, to focus the image of the star so that it is in sharp focus on the slit area.

Use the telescope's guide controls, move the object onto the centre of the slit, so that the slit goes through the centre of the object. Now take a short exposure, between say 1 to 10 seconds, and look at the captured image.

You can judge what sort of exposure you will need by seeing how many counts you get in the captured image. If the spectrum is overexposed it will be saturated, usually with 65k counts and no useful measurements can be made, so adjust the exposure so that no pixels are saturated.

After a little trial and error, you should now have a nice image of the spectrum of your object and you should save the image as a FITS file if you want to analyse the spectrum in detail. A FITS file records the image as a 16 bit data which is 64,000 grey scales and this is needed for accurate measurements and display. The image can also be saved in other formats such as BMP and JPG, but these are only suitable for display purposes.

8: Looking at your first results

If you take a spectrum of single star it will appear as one continuous band across the CCD - all the way from the blue to the red.

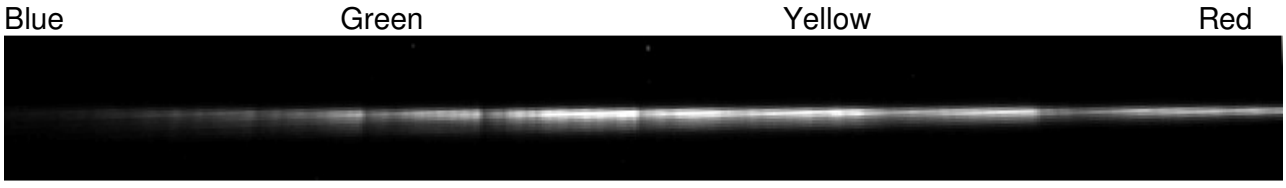


Figure 14 – Spectrum of Scheat (Beta-Peg) an M2 spectral type star.

As the CCDSPEC slit is 5mm in length, you can take a 2 dimensional spectrum of quite a large part of the sky, in which you may be possible to observe several stars at a time and a nebula too, such as shown in the example spectrum of the Orion Nebula in Figure 15.

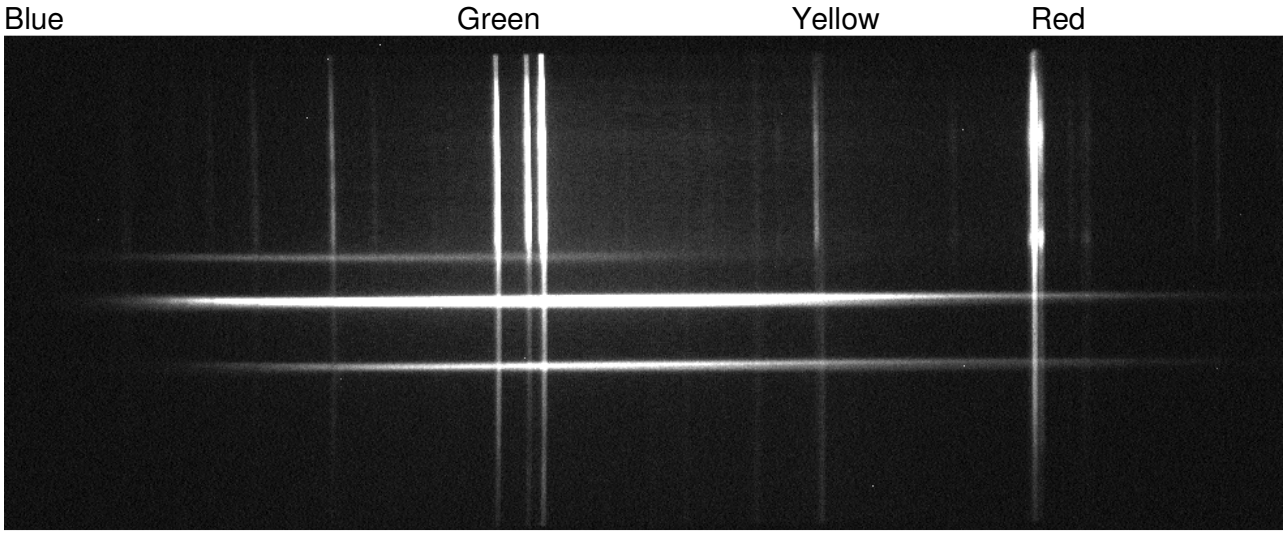


Figure 15 – A spectrum of the Orion Nebula showing the spectra of stars and the hot gas

The spectrum in Figure 15 shows 3 horizontal lines which are continuous spectra of 3 hot stars. The vertical lines are emission from the gas in the nebula, and are very narrow emission lines at discrete wavelengths. So in this one spectrum we have information on both the stars and the gas.

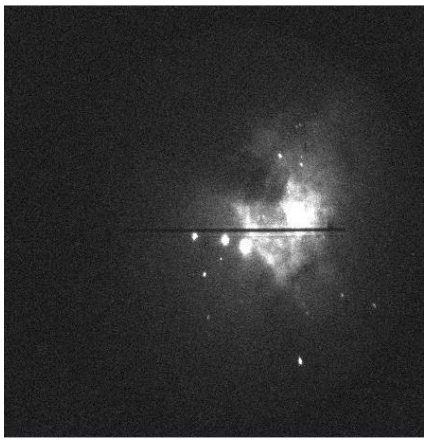


Figure 16 – The Orion Nebula viewed on the slit of the spectrograph

If you want to do any detailed analysis of your spectra, you are recommended to save your CCD image as a FITS file.

9: Plotting your first spectrum

The easiest way to analyse and plot your spectra as graphs is by using the *PCSpectra* software provided on the CCDSPEC CD-ROM. Details of how to install the software are given in the *PCSpectra* Manual.

Start *PCSpectra* and use the File → Open to open your CCD image which was saved as a .fits file

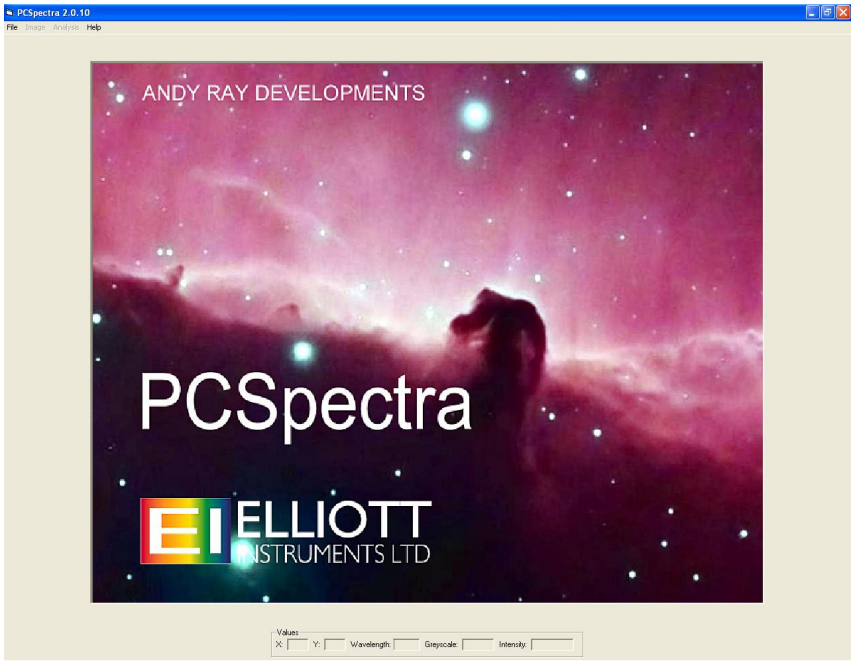


Figure 17 – The start page of *PCSpectra*

The program will display your CCD image of the spectrum and you can use the Image → Set Display Thresholds to adjust the contrast and brightness of the image on the display. This does not change any of your data.

Now, using the mouse, draw a box around the spectrum you wish to see plotted as a graph, and then, from the Image Analysis menu, select SPECTRUM X-axis projection and the program will draw a graph of your spectrum as below

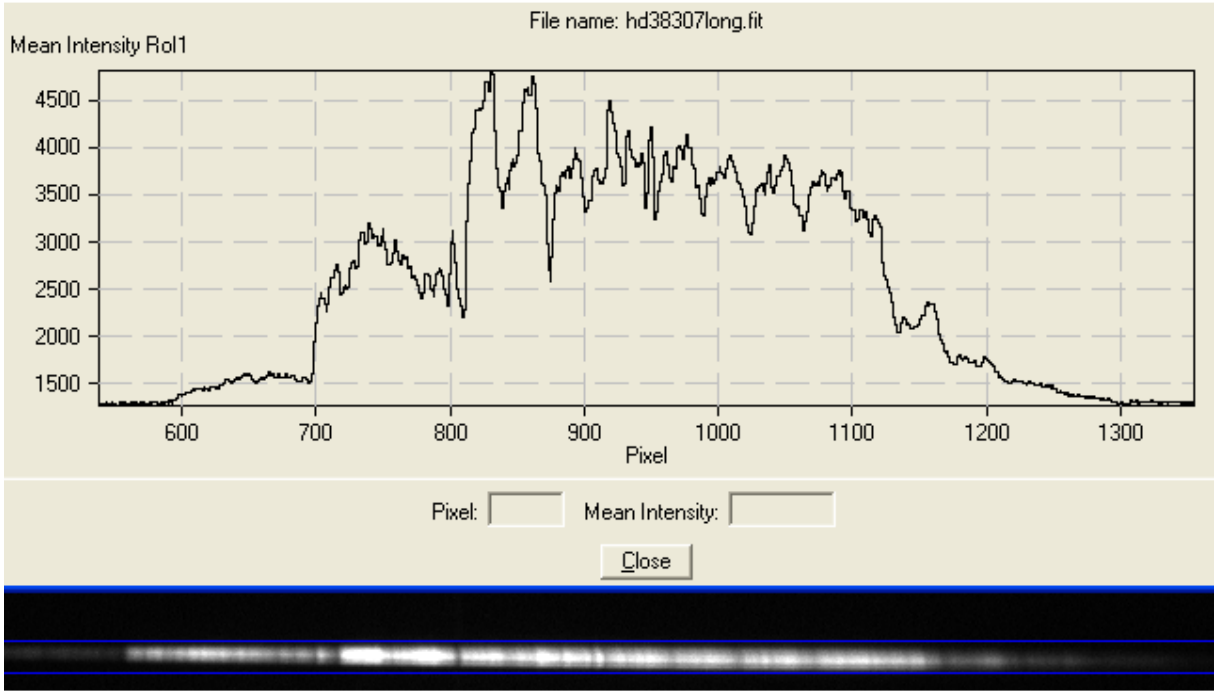


Figure 18 – The image and graph of the spectrum of a carbon star.

The graph can be sent to a printer, saved as a bit map image or you can export the values of the graph as a .csv file so you can use it in a spreadsheet or other program for further analysis.

Now the graph you have at this stage is a plot of spectral brightness versus pixel value on the CCD. If you want to identify the features in the spectrum, so you can determine which atoms and/or molecules are making the absorption/emission lines, then you need to convert the CCD pixel scale into a corresponding wavelength scale in nm. This process is called 'wavelength calibration'.

10: Wavelength Calibration

To obtain a graph of spectral brightness against wavelength in nm, we need to determine the relationship between the pixel number and the wavelength and this is what wavelength calibration is all about. For wavelength calibration, your CCDSPEC needs to be mounted on your telescope so the light passes through the telescope optics into the spectrograph. To illuminate the telescope beam evenly, this is best done by putting a diffuser over the telescope aperture as in Figure 19, and illuminating this with the calibration lamp, or by illuminating the inside of the dome or a white card with the calibration lamp and pointing the telescope at the reflected light. Using the reflected light method with a calibration lamp that isn't very bright may involve taking a long exposure.

Figure 19 - A tracing paper diffuser on the telescope illuminated by a calibration lamp

To obtain an accurate wavelength calibration a number of emission lines of known wavelength, and well spaced along the spectrum is needed. The spectrum of Helium is ideal for this, but other lamps can be used too. Examples of various calibration lamps and their wavelength identifications are shown in the section 15 of this manual.

Take a spectrum of your calibration lamp. This can be a cold cathode lamp, a camping fluorescent lamp or even a mercury or sodium streetlight observed through your telescope. The spectral lines in the lamps can be very bright and be very faint in the same lamp so you may need to take several different exposures. Save your calibration spectrum and open it with *PCSpectra.*

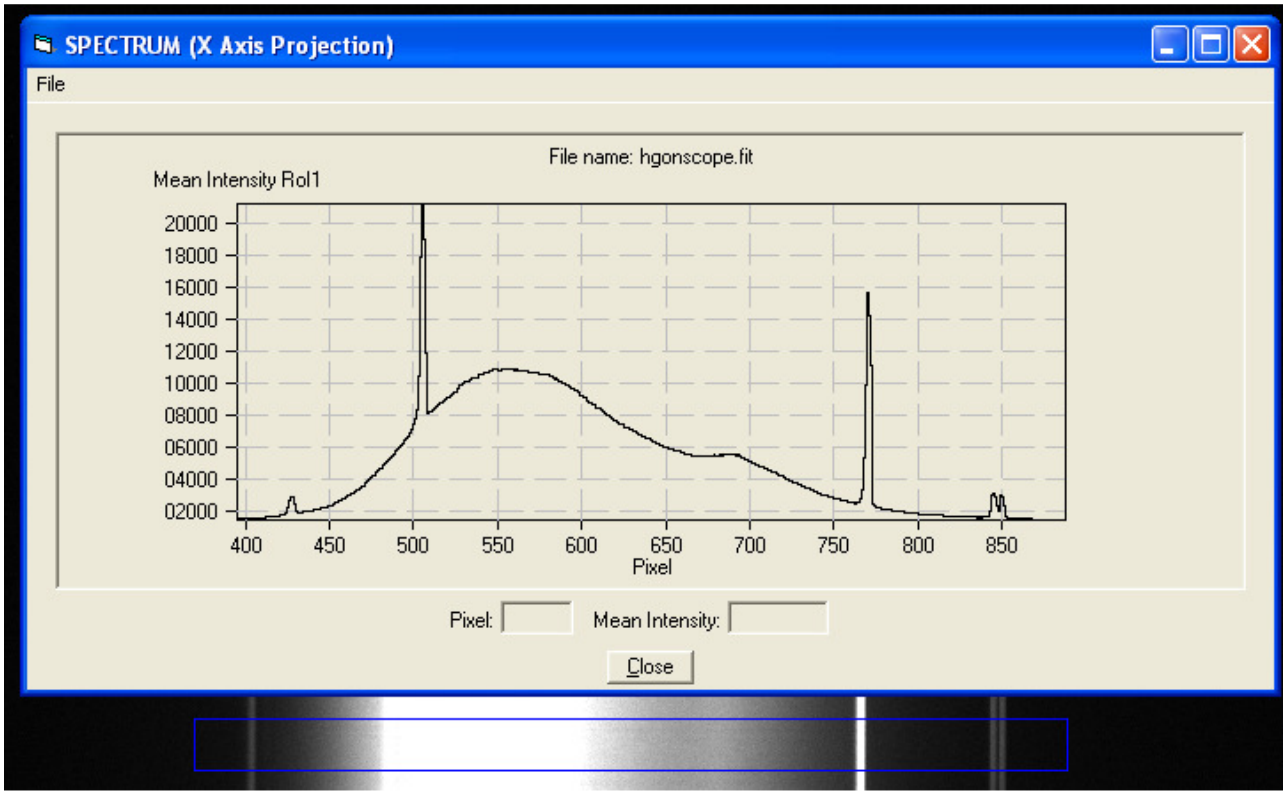


Figure 20 - Spectrum and plot of a cold cathode lamp spectrum

Move the cursor on to the emission line peaks and read off which pixel is at the peak of each lines, so in this case the peaks are at 429, 505, 770, 846 and 851 pixels.

You can measure the position of these lines very accurately (to 0.01 pixel) if you wish using the centroid feature of *PCSpectra* and this is described in the *PCSpectra* Manual

You can now enter these values into the appropriate Calibration Worksheet, which for a cold cathode lamp is the Mercury Calibration Worksheet (see Figure 22), which will calculate the relationship between the pixel on the CCD and the wavelength in nm. Simply put, it calculates the wavelength covered by one CCD pixel and the wavelength at the start of the spectrum in pixel one. The worksheet graph displays these values. So in this case pixel one on the CCD corresponds to a wavelength of 227.06 nm and every pixel has a width of 0.4138 nm. Knowing this we can then calculate the wavelength of any pixel. If you enter these values into a file called SpecCal.txt and copy this into the same folder as your CCD images, then PCSpectra will display your graphs as plots of spectral brightness against wavelength in nm (see Figure 23).

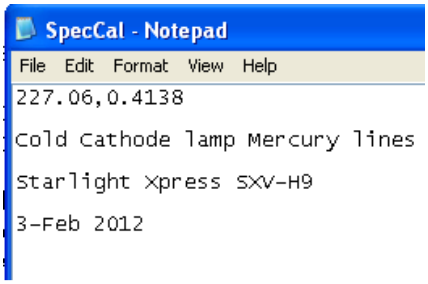
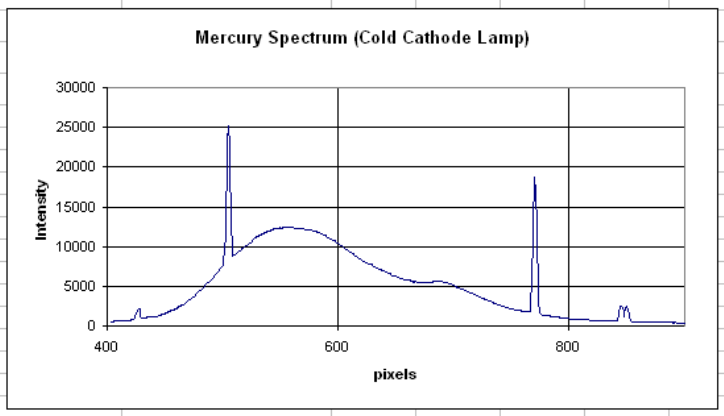


Figure 21 - File SpecCal.txt edited in Notepad

CCDSPEC MERCURY CALIBRATION WORKSHEET

pixel	Mercury Wavelengths (nm)	colour
429	404.66	blue
505	435.83	blue
770	546.07	green
846	576.96	yellow
851	579.07	yellow



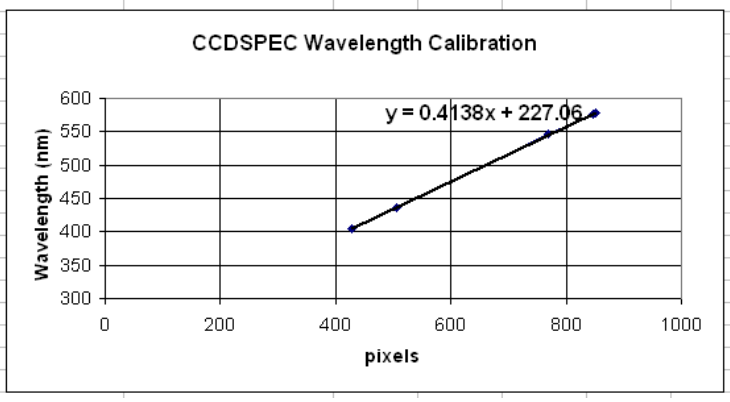


Figure 22 - Mercury Calibration Worksheet

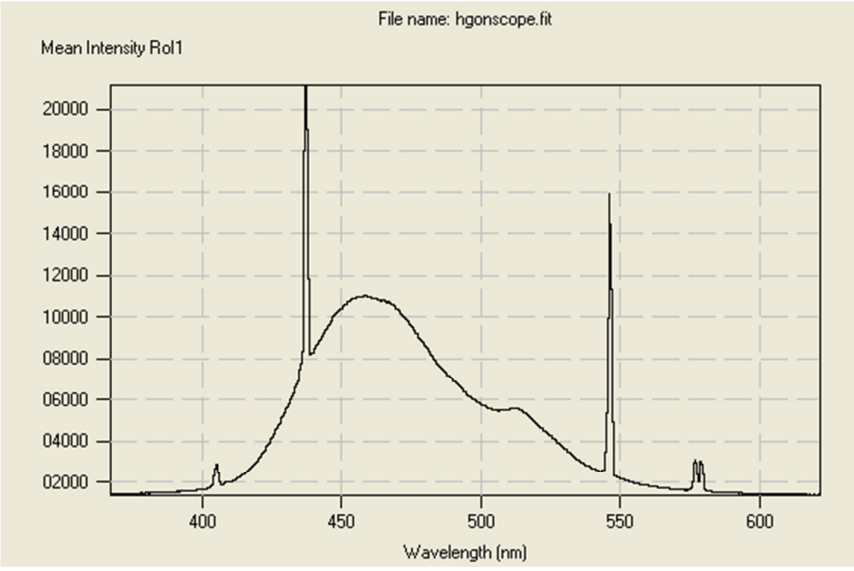


Figure 23 - Graph now calibrated in wavelength (nm)

The Mercury Calibration Worksheet and other calibration worksheets can be found on the CCDSPEC CD-ROM in the worksheet folder.

These can be used with Excel or Open Office Spreadsheet programs.

11: Optical Design

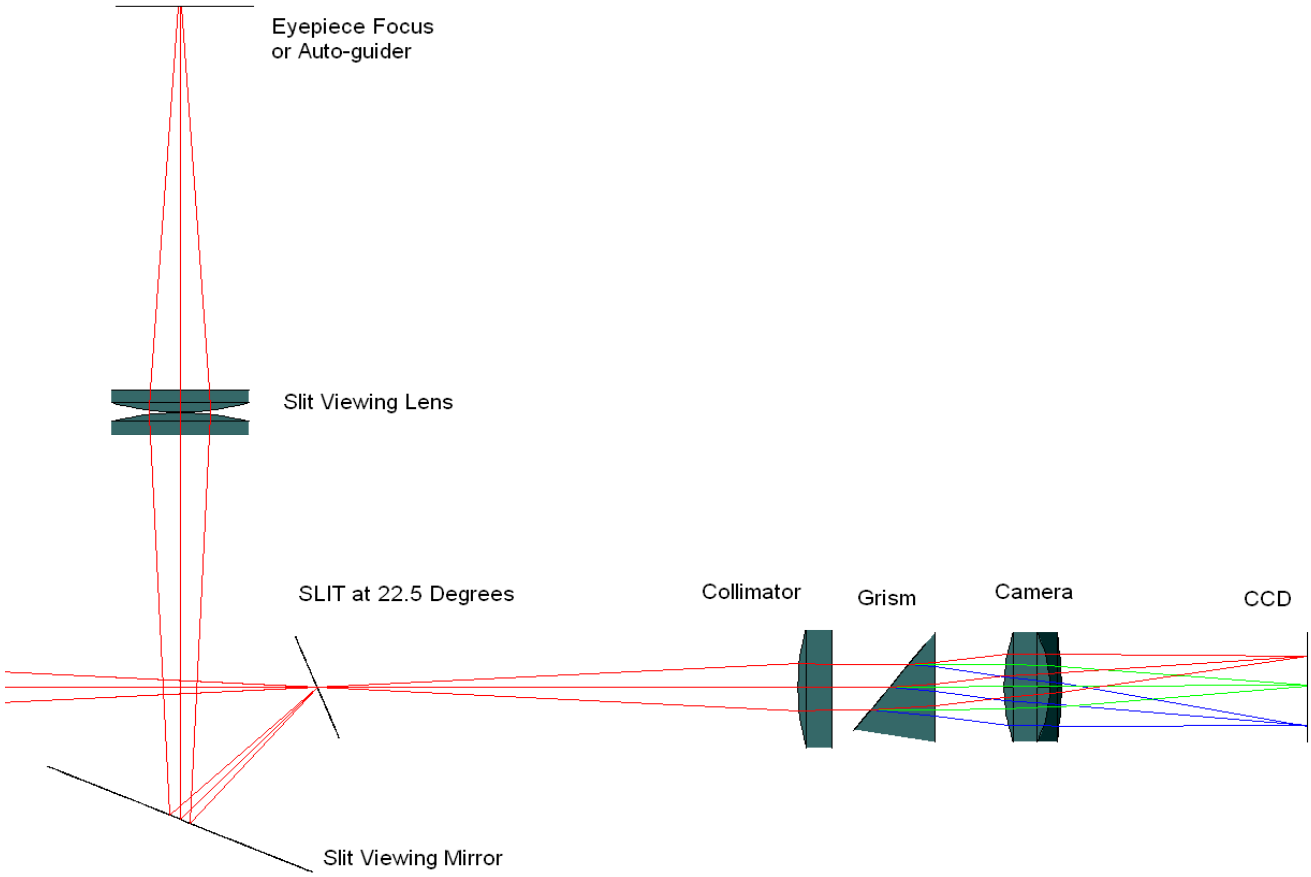


Figure 24 - The optical layout of CCDSPEC

The instrument is attached to a telescope, typically an f/10 Schmidt-Cassegrain Telescope (SCT) by a 1.25" eyepiece adapter or SCT adapter. Light from the telescope is focussed on to the fixed slit which is 50 microns wide by 5mm in length. The slit is tilted at 22.5 degrees to the incoming beam and is highly reflective and any light not passing through the slit is reflected, intercepted by a folding flat into the slit viewing port and is refocused by a lens at the eyepiece or auto-guider. The lens de-magnifies the image of the slit by a factor of 2, so the image in the guiding port is 4x brighter.

The slit disk is 10mm in diameter so gives a large acquisition field of view (17 arc-minutes with an 8" f/10 SCT).

Light passing through the slit is focussed by a lens and the collimated beam enters a grism dispersing the light into a spectrum. The spectrum is focussed on to the CCD detector by a camera lens, which has a vernier focus adjustment, which is accessed through the focus port.

The CCD camera is attached to the CCDSPEC by a special T-mount adapter which has the correct spacing for CCD cameras with a back focus in the range 0-17.5mm.

12: Specification

Construction	CNC machined solid block aluminium
Input Focal Ratio	f/5 –f/30
Minimum Telescope back focus	45mm
Slit Viewing Field of View	10mm
Slit Length	5mm
Slit Width	50 microns appears as ~45 microns at 22.5 degrees
Slit Viewing Magnification	0.5 (4x brighter)
Projected slit width at CCD	~8 microns
CCD back focus	0 – 17.5mm
Linear Dispersion	100nm / mm
Resolution	<1.5nm (400-700nm)
Size	50 x 50 x 160 mm
Weight	890g

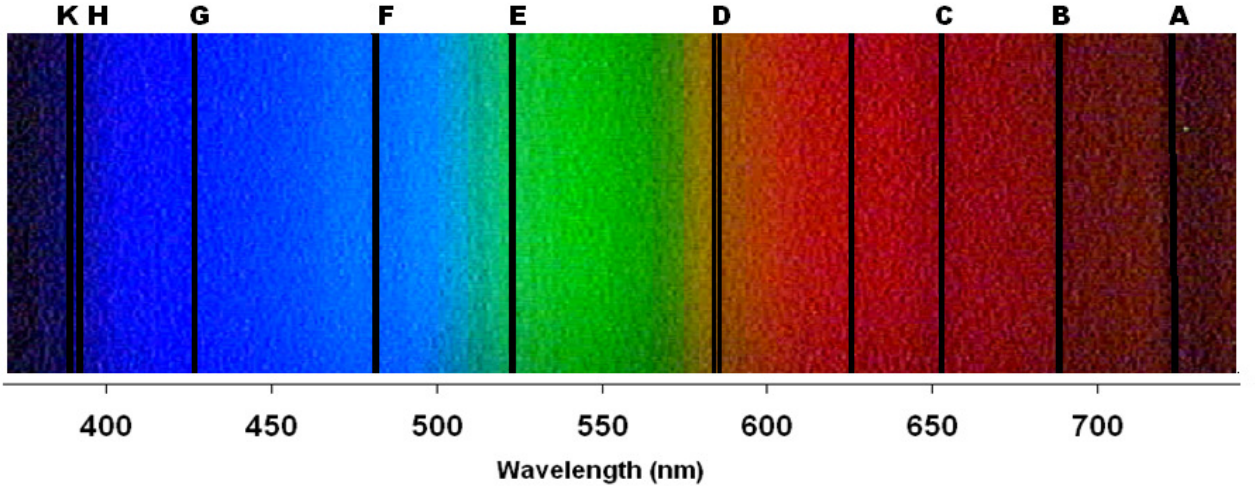


Figure 26 - the Solar Spectrum showing the Fraunhofer lines (Schematic Diagram)

Fraunhofer, in 1817 took a spectrum of the Sun and noticed the dark absorption lines, now named after him and labelled them ABC to GHK. We now know the lines are due to absorption of different elements in the Sun and the Earth's atmosphere. Each element has its own unique atomic fingerprint, just like a DNA fingerprint

C and F is Hydrogen D is Sodium H&K are due to Calcium in the Sun

We can use these "atomic fingerprints" to identify the elements in stars, nebulae and galaxies

What can amateur astronomers achieve?

Stars – Spectral Classification depending on temperature. Discover the strange spectra of very hot and very cool stars. Identify stars with massive stellar winds

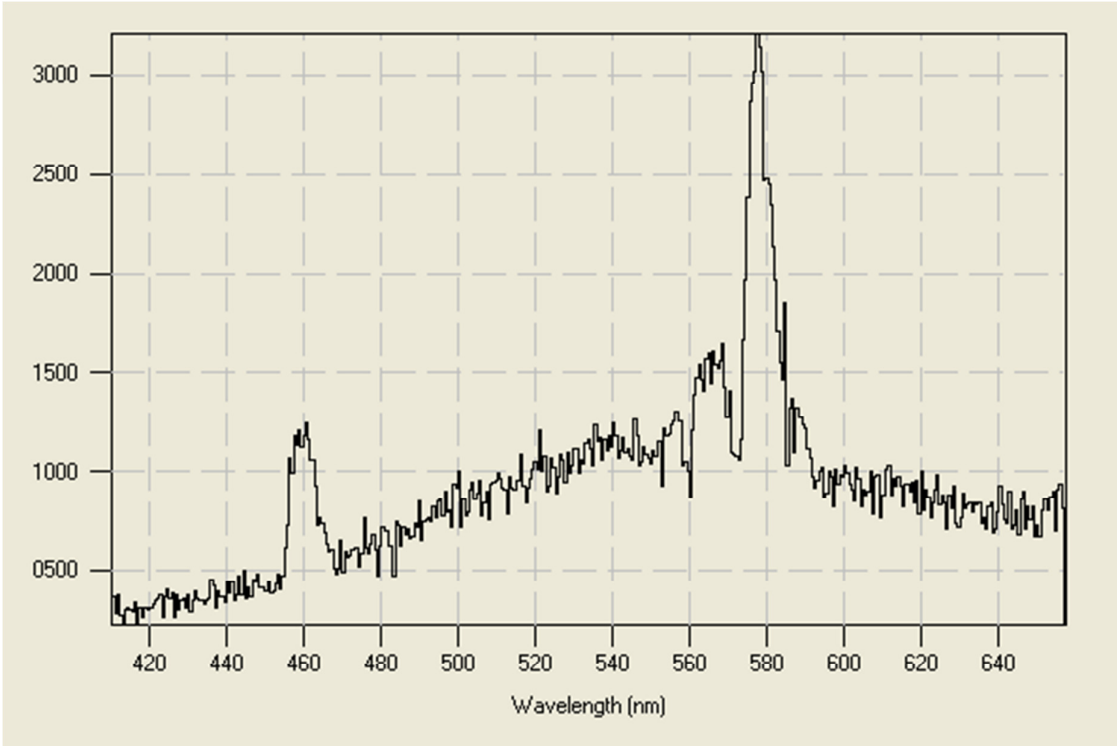


Figure 27 - Wolf-Rayet Star showing wide emission lines indicating a massive stellar wind

Comets & Planets – discover the composition of comets, the atmospheres of planets and their moons

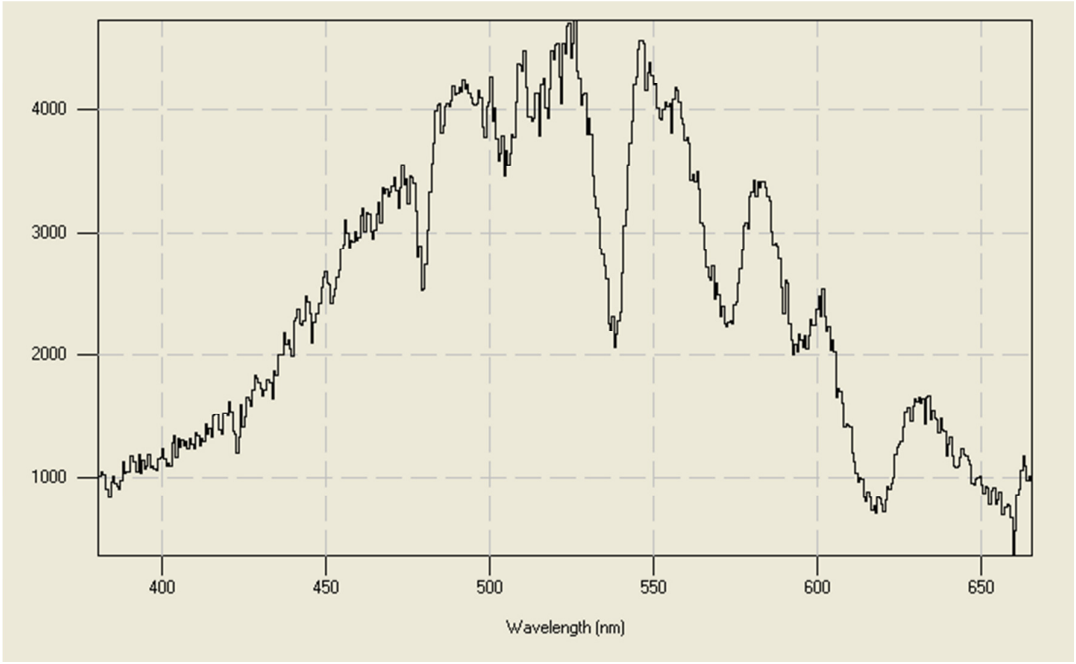


Figure 28 - Spectrum of Uranus showing deep absorption bands due to methane in its atmosphere

Nebulae – find out the properties of the hot gas and measure the expansion of supernova remnants

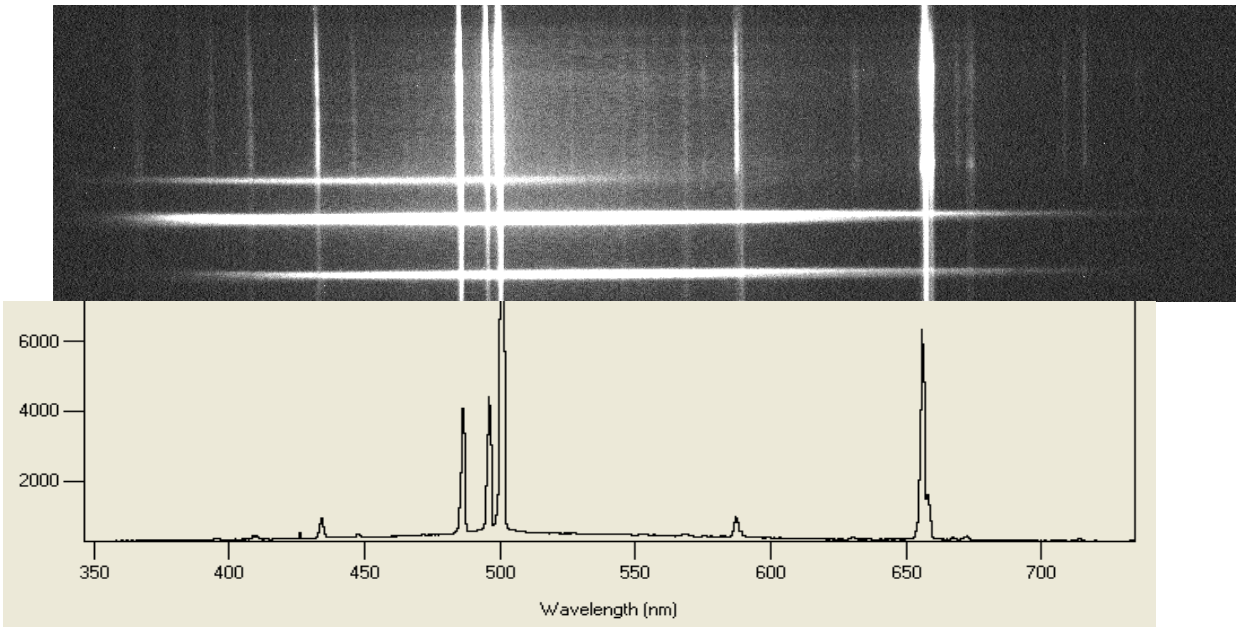


Figure 29 - The spectrum of the Orion Nebula showing the emission lines of Hydrogen Oxygen, Nitrogen and Sulphur. The three horizontal lines are the spectra of very hot stars, which are so hot they show almost no absorption lines

Galaxies and Quasars – Identify active galaxies and measure the redshift (Z).

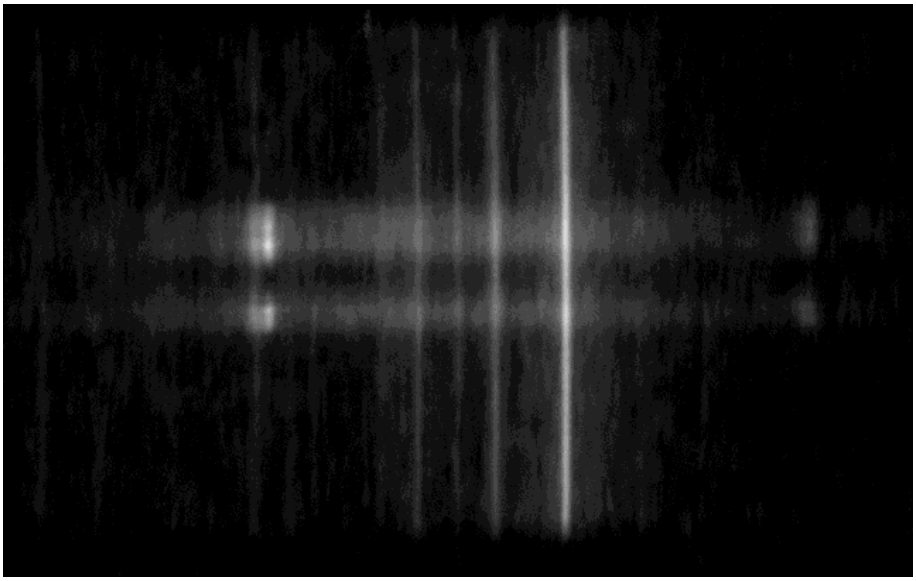


Figure 30 - The spectrum of Active Seyfert Galaxy (M77) showing emission lines of [OIII] and velocity broadened H alpha line. The vertical lines are spectral lines of light pollution from Sodium and Mercury lights

14: Astronomy Resources – List of possible target objects

14.1 Stars

Selected Stars for Spectral Type Determination

Common Name	Constellation	Spectral Type	V - Mag
Alnitak	Zeta - ORI	O9.5	1.79
Mintaka	Delta - ORI	O9.5	2.19
Spica	Alpha-VIR	B1	0.96
El Nath	Beta-TAU	B7	1.65
Regulus	Alpha - LEO	B7	1.35
Rigel	Beta - ORI	B8	0.11
Vega	Alpha - LYR	A0	0.04
Sirius	Alpha - CMA	A1	-1.45
Deneb	Alpha - CYG	A2	1.25
	Alpha - OPH	A5	2.07
	Beta - CAS	F2	2.26
Procyon	Alpha- CMI	F5	0.35
Polaris	Alpha -UMI	F8	2.3
	Alpha - CEN	G2	-0.1
Capella	Alpha-AUR	G8	0.08
Pollux	Beta-GEM	K0	1.15
Dubhe	Alpha - UMA	K0	1.79
Arcturus	Alpha - BOO	K2	-0.6
Alderbaran	Alpha - TAU	K5	0.85
Mirach	Beta - AND	M0	2.06
Betelgeuse	Alpha-ORI	M2	0.8
Mira	Omicron - CET	M6	2

Selected Wolf-Rayet Stars

Name	HD	RA	Dec	Type	V - mag
WR 4	16523	2 41 11.6	+56 43 50	WC5	9.98
WR 6	50896	6 54 13.0	-23 55 42	WN5	6.74
WR110	165688	18 07 57.0	-19 23 56	WN6	9.81
WR111	165763	18 08 28.5	-21 15 11	WC5	7.68
WR113	168206	18 19 07.4	-11 37 58	WC8	9.18
WR133	190918	20 05 57.3	+35 47 17	WN4	6.78
WR134	191765	20 10 14.2	+36 10 35	WN6	8.02
WR135	192103	20 11 53.5	+36 11 51	WC8	8.51
WR136	192163	20 12 06.5	+38 21 17	WN6	7.44
WR137	192641	20 14 31.8	+36 39 39	WC7	7.95
WR138	193077	20 17 00.0	+37 25 23	WN5	8.06
WR139	193576	20 19 32.4	+38 43 54	WN5	8.27
WR140	193793	20 20 28.1	+43 51 17	WC7	6.88
WR141	193928	20 21 31.8	+36 55 13	WN6	9.74
WR153	211853	22 18 45.6	+56 07 35	WN6	9.03
WR155	214419	22 36 54.0	+56 54 21	WN7	8.86

Selected P-Cyg Stars

Name	RA (2000.0)	Dec (2000.0)	Sp	V - mag
HD 12953	02 08 40.6	58 25 25	A2	5.9
HD 21389	03 29 54.7	58 52 43	A0	4.8
HD 31964	05 01 58.1	43 49 24	F2	3.4
HD 174638	18 50 04.8	33 21 45.6	B	3.4
HD 190603	20 04 36.2	32 13 06.9	B2	5.7
HD 193237 *	20 17 47.2	38 01 58.5	B1	4.9
HD 197345	20 41 25.9	45 16 49.2	A2	1.3
HD 198478	20 48 56.3	46 06 50.9	B2	4.9
HD 223385	23 48 50.2	62 12 52.2	A3	5.6

* P-CYG

14.2 Selected Diffuse Nebulae

Name	Type	NGC
Crab Nebula	SNR	1952
Orion Nebula	HII Region	1976
Tarantula Nebula	HII Region	2070
Rosette Nebula	HII Region	2237
Carina Nebula	HII Region	3372
Trifid Nebula	HII Region	6415
Lagoon Nebula	HII Region	6523
M16	HII Region	661
M17	HII Region	6618
Cygnus Loop	SNR	6960
N America Nebula	HII Region	7000
Crescent Nebula	WR Nebula	6888
Bubble Nebula	WR Nebula	7635

14.3 Selected Nebulae Planetary Nebulae listed by surface brightness

Name	-Log(Hβ) Flux	Diam arcsec	Surface brightness
SwST1	10.33	1.5	10000
Hb 12	10.91	1	5918
IC4997	10.81	1.6	2910
Fg3	10.9	2	1513
Hu 2-1	10.75	2.6	1265
NGC6644	10.88	2.6	938
NGC6572	9.72	11	757
He2-131	10.34	6	610
IC418	9.9	12	420
NGC5315	10.6	6	335
IC4191	11.02	5	183
BD+30 3639	10.68	7.5	178
IC4776	10.69	7.5	174
NGC7027	10.3	14	123
IC4364	10.82	8.4	103
NGC6578	11.53	4	88
NGC6790	11.05	7	87

NGC6803	11.32	5.5	76
NGC6884	11.26	6	73
IC2003	11	8.7	63
NGC6886	11.43	5.5	59
NGC6543	10.35	19.5	56
IC2553	11.05	9	52
NGC6575	11.22	7.6	50
NGC6439	11.62	5	46
NGC6879	11.7	5	38
NGC5873	11.41	7	38
IC5217	11.47	6.6	37
IC351	11.48	7	32
IC4699	11.79	5	31
IC4593	10.98	13	29
NGC6210	10.83	16	27
IC2448	11.34	9	27
NGC5882	11.08	14	20
NGC6826	10.58	25	20
NGC6741	11.57	8	20
IC3568	11.39	10	19
NGC6620	11.78	8	12
NGC6891	11.25	15	12
NGC2867	11.37	14	10
NGC6818	11.25	20	6
NGC2440	11.41	17	6
NGC7009	10.98	28.5	6
NGC3918	11.35	19	5
NGC6326	11.75	12.5	5

14.4 Selected Active Galaxies

Name	Type	V -mag	Z
M77 (NGC1068)	Seyfert 2	10.5	0.003
NGC 4151	Seyfert 1	12	0.003
NGC4261	AGN with SMBH	11.4	0.007
3C273	QSO	12.8	0.158
Mrk 79	Seyfert 1	13.4	0.02
NCC 1052	LINER	13.5	0.005
OJ 287	BL Lac	14	-
BL Lac	BL Lac	14.5	0.069
3C120	Radio Galaxy	14.6	0.033

15.1 Astronomical Spectral Line Identifications - Fraunhofer Lines

Element	Wavelength (nm)
Fe	302.108
Ti+	336.112
Fe	358.121
Fe	382.044
Ca+	393.368
Ca+	396.847
Hδ	410.175
Ca	430.774
Fe	430.79
Hγ	434.047

Fe	438.355
Fe	466.814
Hβ	486.134
Fe	495.761
Mg	516.733
Fe	516.891
Fe	516.891
Mg	517.27
Mg	518.362
Fe	527.039
Hg	546.073
He	587.562
Na	588.995
Na	589.592
O2	627.661
Hα	656.281
O2	686.719
O2	759.37
O2	822.696
O2	898.765

O2	is in Earth's Atmosphere

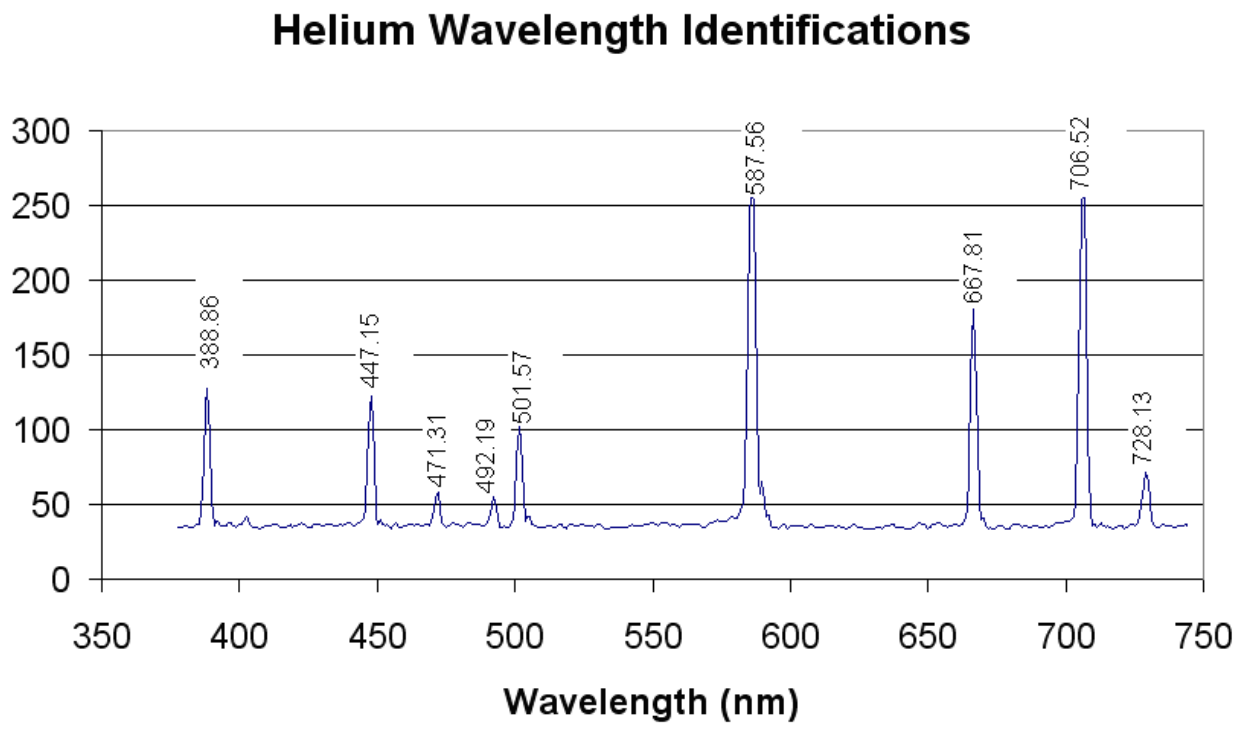
Nebular Emission Lines

Wave (Angström)	Ident	Wave (Angstrom)	Ident
4009.22	He I	5545	N I
4026.08	N II	5545.15	N I
4026.21	He I	5577.34	[O I]
4068.6	[S II]	5666.64	N II
4076.35	[S II]	5679.56	N II
4101.74	H I	5686.21	N II
4120.82	He I	5710.76	N II
4143.76	He I	5754.64	[N II]
4267.15	C II	5875.64	He I
4303.61	O II	5978.83	Si II
4303.82	O II	6046.44	O I
4319.63	O II	6300.3	[O I]
4326.4	O I	6312.1	[S III]
4340.47	H I	6347.11	Si II
4345.56	O II	6363.78	[O I]
4363.21	[O III]	6371.36	Si II
4368.25	O I	6461.95	C II
4387.93	He I	6462.13	C II
4437.55	He I	6548.03	[N II]
4471.48	He I	6562.82	H I
4562.6	Mg I	6578.05	C II
4571.1	Mg I	6583.41	[N II]
4607.06	[Fe III]	6678.15	He I
4607.16	N II	6716.47	[S II]
4621.39	N II	6730.85	[S II]
4630.54	N II	7002.23	O I
4638.86	O II	7065.28	He I
4641.81	O II	7111.47	C I
4643.06	N II	7113.18	C I
4649.13	O II	7115.17	C I

4650.84	O II	7116.99	C I
4658.1	[Fe III]	7135.78	[Ar III]
4661.63	O II	7155.14	[Fe II]
4701.53	[Fe III]	7231.12	C II
4711.37	[Ar IV]	7236.19	C II
4713.14	He I	7254.38	O I
4733.91	[Fe III]	7281.35	He I
4754.69	[Fe III]	7298.05	He I
4769.43	[Fe III]	7318.39	[O II]
4814.55	[Fe II]	7319.99	[O II]
4815.51	S II	7329.66	[O II]
4861.33	H I	7330.73	[O II]
4881	[Fe III]	7377.83	[Ni II]
4921.93	He I	7423.64	N I 3
4958.91	[O III]	7442.3	N I 3
5006.84	[O III]	7452.54	[Fe II]
5015.68	He I	7468.31	N
5032.43	S II	7499.85	He I
5041.03	Si II	7751.1	[Ar III]
5047.74	He I	7771.94	O I
5055.98	Si II	7782.18	Mn I
5056.31	Si II	7801.79	V
5158.78	[Fe II]	7816.13	He I
5197.9	[N I]	7837.85	[Co I]
5200.26	[N I]	7862.85	Fe II]
5270.4	[Fe III]	7875.99	[P II]
5517.71	[Cl III]	7959.7	N I
5537.88	[Cl III]		

(10 Angström = 1nm)

15.2 Calibration Spectra and Line Identifications



Wavelength (nm)

Figure 31 - Helium Calibration Spectrum

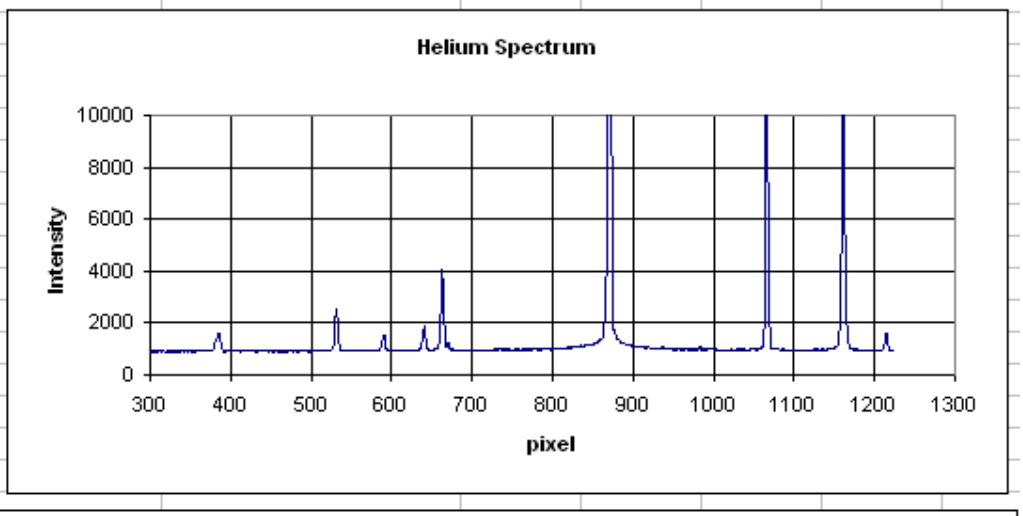
List of principal wavelengths found in spectral lamps

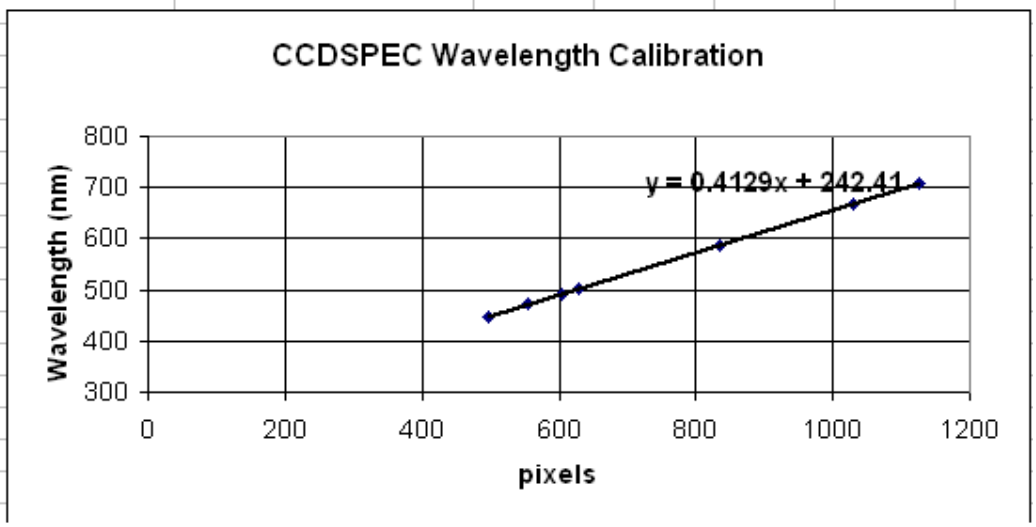
Wave (nm)	Ident
366.33	Hg
388.87	He
404.66	Hg
407.78	Hg
407.78	Hg
410.12	H
434.01	H
435.84	Hg
447.14	He
471.31	He
486.07	H
492.19	He
501.57	He
546.07	Hg
576.96	Hg
579.07	Hg
587.56	He
588.99	Na
589.59	Na
623.44	Hg
656.21	H
667.81	He
690.75	Hg
706.52	He
728.13	He

15.3 Calibration Wavelength Worksheets

CCDSPEC HELIUM CALIBRATION WORKSHEET

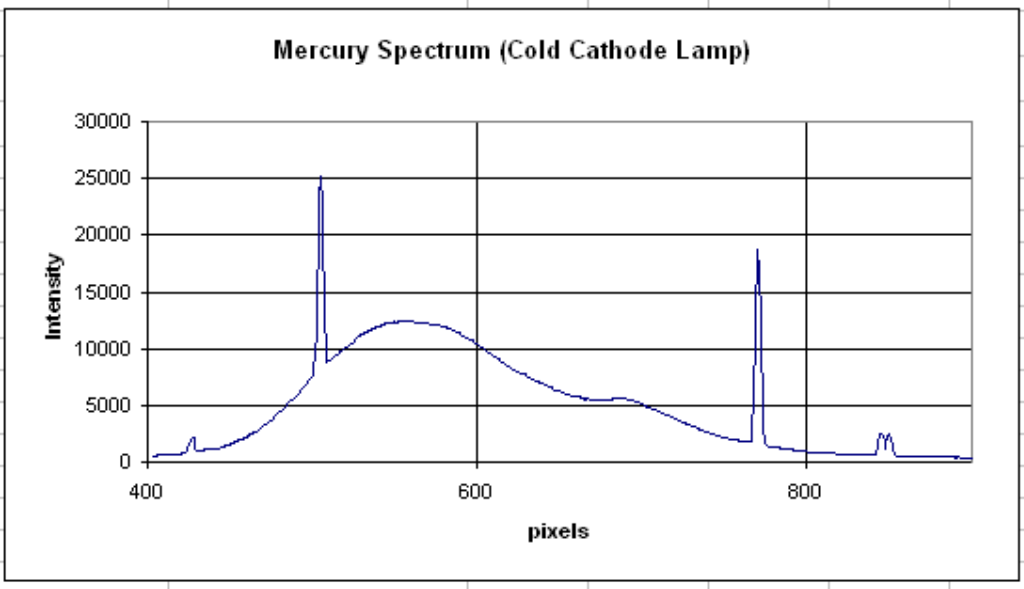
pixel	Helium Wavelengths (nm)	colour
	388.87	UV
496.45	447.15	blue
554.81	471.31	blue
604.99	492.19	green
627.5	501.57	green
833.67	587.56	yellow
1029.21	667.81	red
1125.8	706.52	IR
	728.13	IR

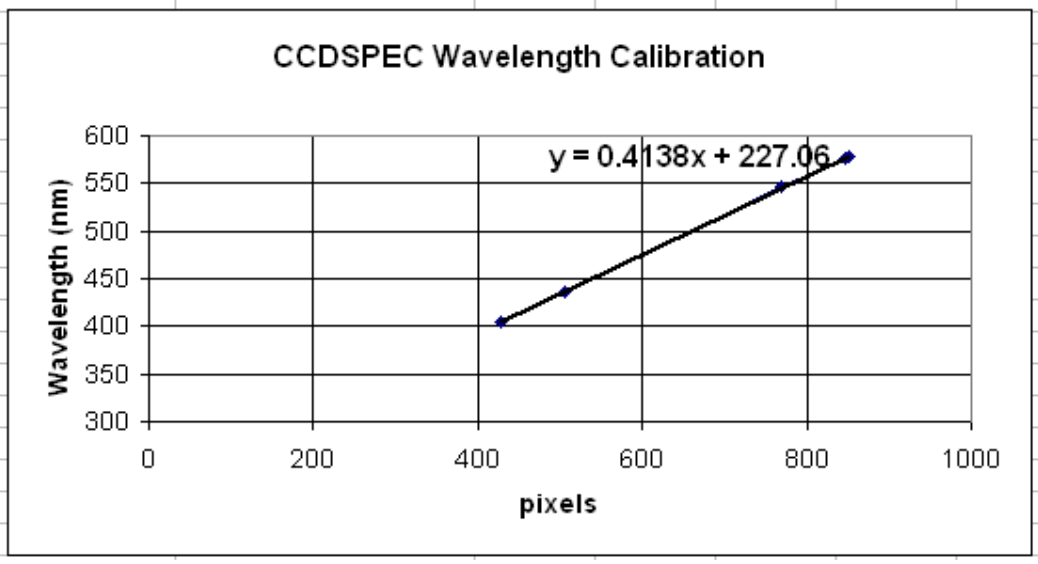




CCDSPEC MERCURY CALIBRATION WORKSHEET

pixel	Mercury Wavelengths (nm)	colour
429	404.66	blue
505	435.83	blue
770	546.07	green
846	576.96	yellow
851	579.07	yellow





16: An Introduction to PCSpectra Software

16.1: Installation of PCSpectra Software

Insert the CCDSPEC CD-ROM into your drive and open the folder PCSpectra and run the installation program by double clicking on setup.exe and follow the instructions. When installed the PCSpectra application can be run by selecting Start->All Programs->PCSpectra->PCSpectra 2.0.xx or by dragging the application icon on to your desktop, and running from the desktop.

16.2: Summary of Functions (full details in the Reference Manual)

The main controls are via the following menu options

File **Image** **Analysis** **Help**

File → Open This will open and display and image of your spectrum on your PC.

Image →

Information - basic data about the image - dimensions and max min etc

Zoom – allows image to be fitted to window or zoom in or out

Invert Display – makes the image display a negative

Set Display Thresholds - allows you to change the contrast of the display

Display Settings – Allows you to save your contrast settings and use them again

Analysis →

SPECTRUM (X-Axis Projection) – if you use the mouse to draw a box round the image of your spectrum then option this draws an intensity graph of your spectrum, which can be printed or saved.

PROFILE (Y-Axis Projection) – draws and intensity graph along the length of the slit

Centroid and Area Measurement – finds the centre and area on any feature such as a spectral line, which is selected by using the mouse to draw a box round the feature and selecting the intensity thresholds.

Invert (Maximum - Intensity) – inverts the spectrum so that an absorption line becomes and emission line for centroid measurement.

Set Data Thresholds – to exclude features from the centroid program, you can set a threshold in intensity below which the data isn't used to find the centre.

Set Region of Interest Size and Position – Up to two regions of interest can be specified either by using the mouse, or by entering the coordinates via this option.

The two regions of interest can be added or subtracted, so for instance you can subtract the sky background from a spectrum of a star.

This option also allows you choose to display pixels or wavelength on the spectral graph and either the mean intensity or the summed intensity in the spectrum

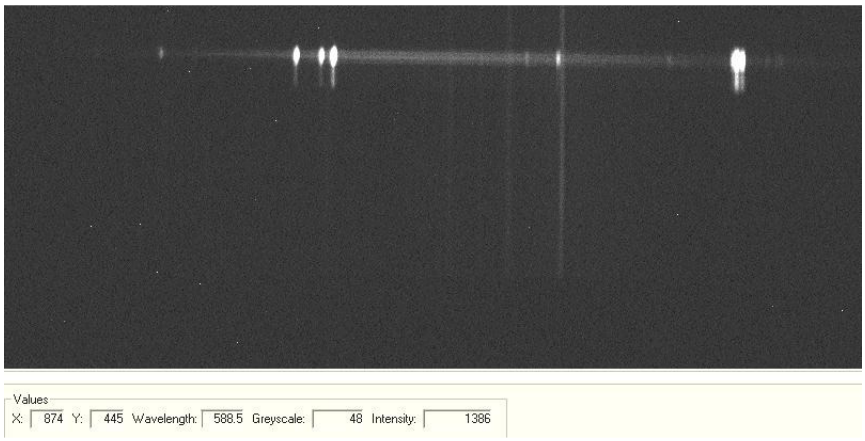
Display Region of Interest – Displays the ROI in it's own window

Histogram (Intensity Distribution) – plots a graph of the number of pixels as a function of their brightness

Analysis Settings – Allows you to save you regions of interest so they can be used again.

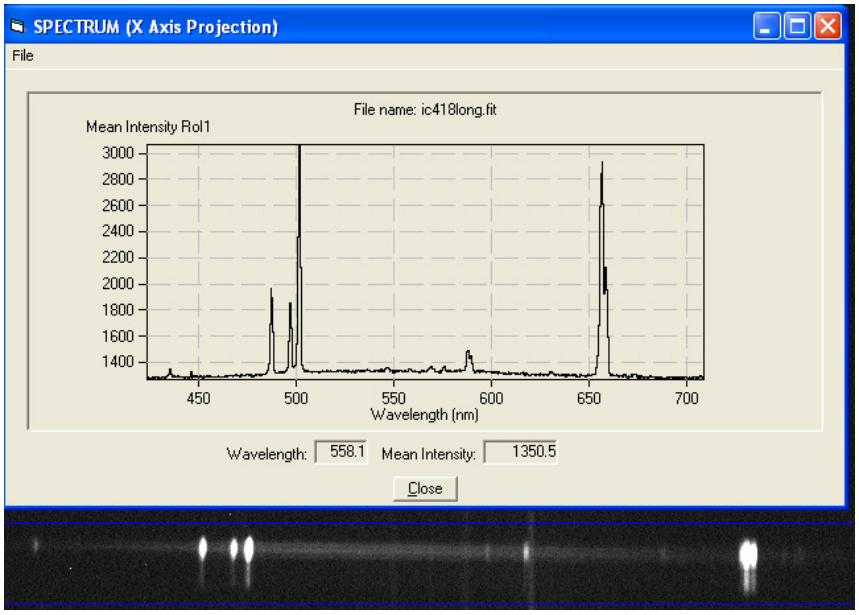
16.3: Example of Using PCSpectra

Here is a spectrum of a planetary nebula as displayed by PCSpectra.

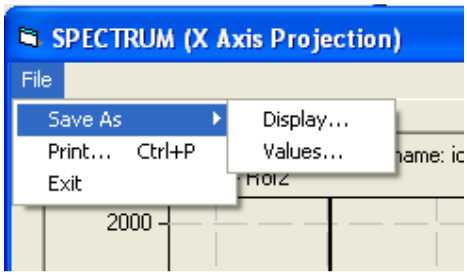


The planetary nebula is the horizontal line with the bright emission lines on top of the continuum. You can also see very long vertical lines which is light pollution. At the bottom of the display shows the X and Y coordinates of the cursor and the wavelength as well as the intensity level in the data (0-65536) and the grey scale value of the display (0-255)

We can get a graph of spectrum of the planetary nebula simply by using the mouse and cursor to draw round the image of the spectrum and then use the Analysis → SPECTRUM (X-Axis Projection) option as below

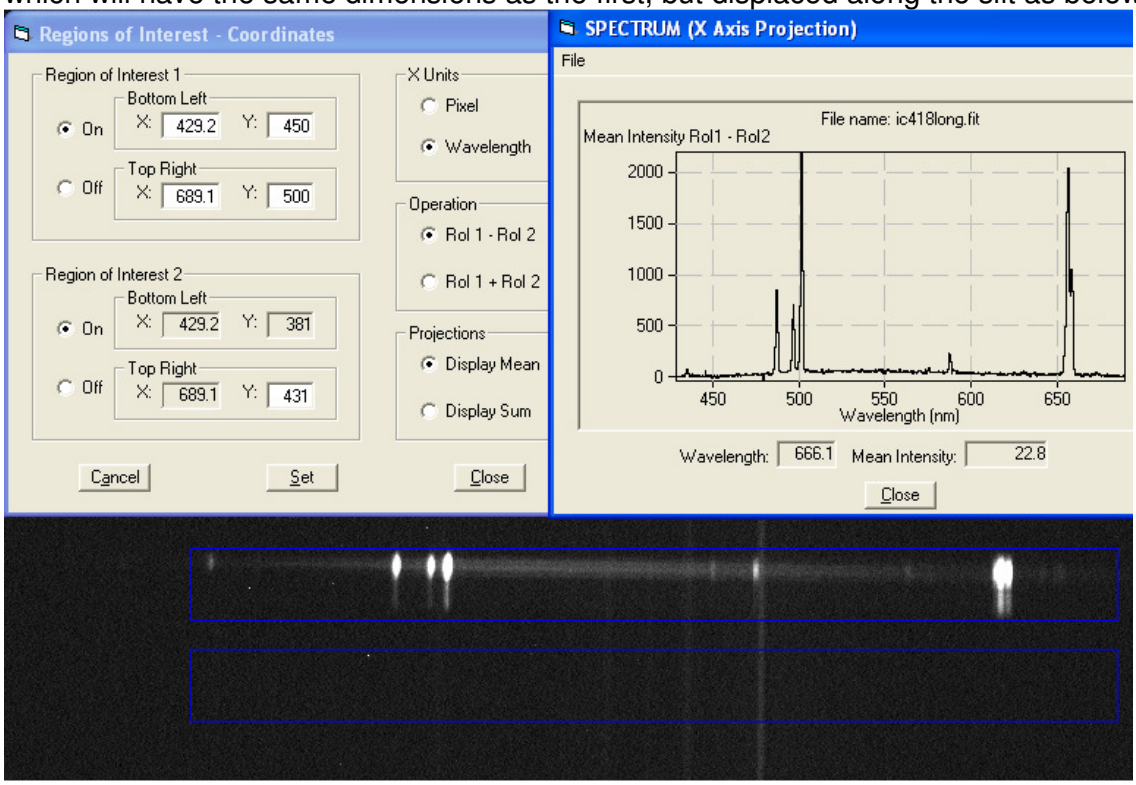


From the file option on the Analysis → SPECTRUM (X-Axis Projection) the graph can be printed or can be saved as a bitmap, or the values in the graph can be saved as a .CSV file for further analysis eg by a spreadsheet.



If you wish to subtract the light pollution lines, you can select two regions of interest (ROI) and subtract one from another.

First draw the first ROI with the mouse. Now pressing the shift key, select the second ROI which will have the same dimensions as the first, but displaced along the slit as below.

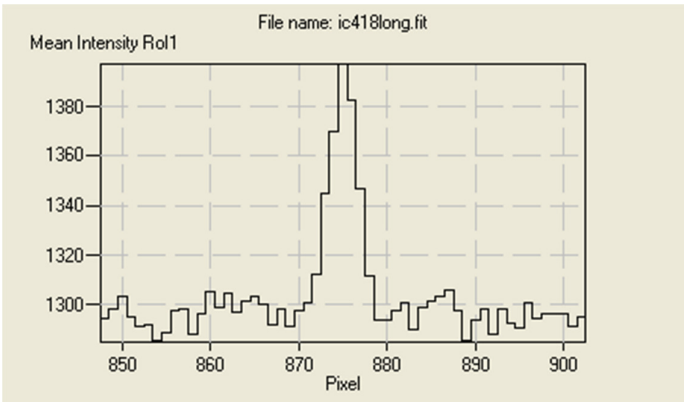


Then select which operation you require eg ROI1 – ROI2 and press the Set button and the graph will now show the sky subtracted spectrum.

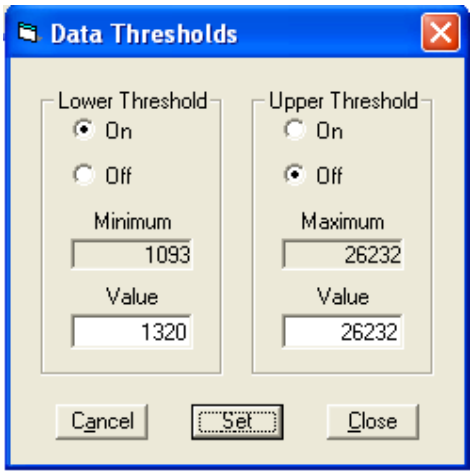
16.4: Accurate Measurement of Spectral Lines

You can get rough values of the positions of spectral lines by simply putting the cursor on the line and finding the position of the maximum intensity. However PCSpectra allows you to measure the position of the line much more accurately by using the centroid method and an example is given here.

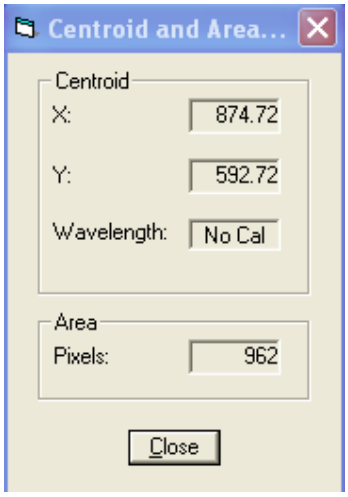
First of all use the mouse and cursor to draw a box (ROI) around the spectral line of interest and use the Analysis → SPECTRUM (X-Axis Projection to get a graph of the intensity of the line.



Choose a lower threshold clear of the noise in this case at say 1320 and enter this in the Analysis → Set Data Thresholds, switch on the lower threshold and press Set.



Now select Analysis → Centroid and Area Measurement and the centre of the line will be displayed.



The X value is the centroid of the spectral line and can be as accurate as 0.01 pixels if the data is good quality. If the data is wavelength calibrated the result will be in wavelength (nm).

16.5: Absorption lines can also be analysed in this way, but they need to be converted into emission lines by using the Analysis → Invert (Maximum - Intensity) option.

17: Internet Resources

Atomic Line List http://www.pa.uky.edu/~peter/atomic/index.html

Interactive Database of Spectral Standard Star Atlases
http://spectra.freeshell.org/SpectroWeb_ctrl.html

Astronomical Almanac Online http://asa.usno.navy.mil/

Club of Amateurs in Optical Spectroscopy http://www.eso.org/projects/caos/

The Sun Data http://www.jgiesen.de/astro/astroJS/rsTableWorld/index.htm

Spectral Lamp Data http://laserstars.org/data/elements/index.html

Stark-Labs supplier of Nebulosity CCD Control Program ($60) and PHD guiding software (FREE).
http://www.stark-labs.com/

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CCDSPEC patent pending 1120579.6

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Any comments or suggestions, or problems with the installation or use of CCDSPEC should be addressed to Dr K H Elliott at the address below.

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